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B. T. GALLOWAY, Chief of Bureau.

THE SULPHUR BLEACHING OF COMMERCIAL OATS AND BARLEY.

BY

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THE SULPHUR BLEACHING OF COMMERCIAL OATS AND BARLEY.

INTRODUCTION.

When a crop of oats or of barley is harvested under adverse weather conditions, or in a careless manner, there is generally a deterioration in both the quality and condition of the grain which reduces its market value. In order to make grain thus damaged appear sound, healthy, and bright, and also to remove the objectionable odors which are usually present, such grain is often artificially bleached with sulphurous acid, thereby making it possible to realize a higher price from its sale.

The bleaching of grain, and especially the bleaching of oats, with sulphurous acid has been practiced in many of the larger grain markets for a considerable number of years, but with the comparatively recent developments in apparatus for bleaching grain rapidly and inexpensively the practice has become common also in the smaller grain centers. The process of bleaching is ordinarily referred to in the grain markets as "purifying," and grain so treated is sometimes sold as "purified" grain, no mention being made of its having been bleached or of sulphur having been used in the process of bleaching.

Based on investigations carried on at 13 grain markets in 3 of the leading oat-producing States, it is estimated that 18,732,000 bushels of oats and barley were bleached in those markets during the six months from October, 1908, to March, 1909, inclusive. The best data available show that during the same period approximately 75 per cent of the low-grade oats, ordinarily No. 4 White or below, received at those markets were sulphur bleached.

Sulphur-bleached oats are marketed chiefly in New England and in such of the Eastern and Southern States as do not produce enough oats for home consumption. On account of the bright and attractive appearance of the bleached grain, it is often selected in preference to the unbleached.

Laws have been enacted in several of the States under the authority of which the food commissions of those States have held it to be unlawful to offer sulphur-bleached or chemically treated grain for sale within those States except when it is so labeled.

The views of the Board of Food and Drug Inspection of the United States Department of Agriculture[a] with respect to the use of sulphur dioxid in foods are as follows:

> No objection will be made to foods which contain the ordinary quantities of sulphur dioxid if the fact that such foods have been so prepared is plainly stated upon the label of each package. An abnormal quantity of sulphur dioxid placed in food for the purpose of marketing an excessive moisture content will be regarded as fraudulent adulteration under the food and drugs act of June 30, 1906, and will be proceeded against accordingly.

In some States the laws and in other States the grade rules under which the grain-inspection departments work prohibit the grading of bleached or chemically treated oats and barley, but owing to the difficulty of distinguishing, except in extreme or exceptional cases, between the bleached and unbleached grain without submitting it to a chemical test, these prohibitions are not always carried out. When such grain is refused a grade it is designated as "purified" by the inspectors and sold by sample instead of by grade.

Selling bleached oats by sample has always been more or less unsatisfactory and has led to many disputes between buyer and seller. In marketing this class of grain, when it is not designated as "purified" it is customary to make up standard samples to which trade names are often given. These samples are sent to prospective buyers invariably in cloth sacks of open fiber which allow the sulphurous-acid odor to be dissipated. Upon delivery of the grain on the basis of these samples, the odor of sulphurous acid is readily detected and the buyer is dissatisfied because he believes the car of grain delivered is not like the original sample.

METHOD OF SULPHUR BLEACHING.

There are several types of grain bleachers in use, the most common of which is the "tower" or "chimney" bleacher, so called because of the style of its construction. The different forms of this type vary principally in the manner of distributing the grain at the top and in the way in which it passes through the bleacher. These tower bleachers are constructed of brick, masonry, or wood covered with galvanized iron; and for convenience in handling the grain through them the towers are built close to the elevator, the top of the tower usually corresponding with the upper working floor of the elevator, which may be at a height of 25 to 60 feet above the ground. On the interior of the bleaching tower, which is about 3 or 4 feet square, are alternating series of deflecting shelves set at an angle of about 45° to the horizontal plane. The purpose of these shelves is to retard the movement of the grain and to distribute it evenly through the tower after it falls from the spout at the top, as shown in figure 1.

[a] Food Inspection Decision No. 89, U. S. Department of Agriculture, Mar. 5, 1908.

As practiced commercially, sulphur is burned in a furnace or oven located some distance from the bleaching tower as a precaution against fire. The burning sulphur coming in contact with the oxygen of the air forms sulphur-dioxid gas, which is forced into the bleaching tower 8 or 10 feet from its base through a pipe leading from the furnace.

In order that the bleaching may be accomplished this sulphur-dioxid gas must come in contact with water and unite with it, in which case it forms sulphurous acid, which is the bleaching agent. For this reason the grain, as it passes into the bleaching tower at the top, is dampened with either a jet of steam or small sprays of water. The sulphur-dioxid gas, circulating upward, unites with the moisture adhering to the outside of the downward-moving grain, thereby making the bleaching possible.

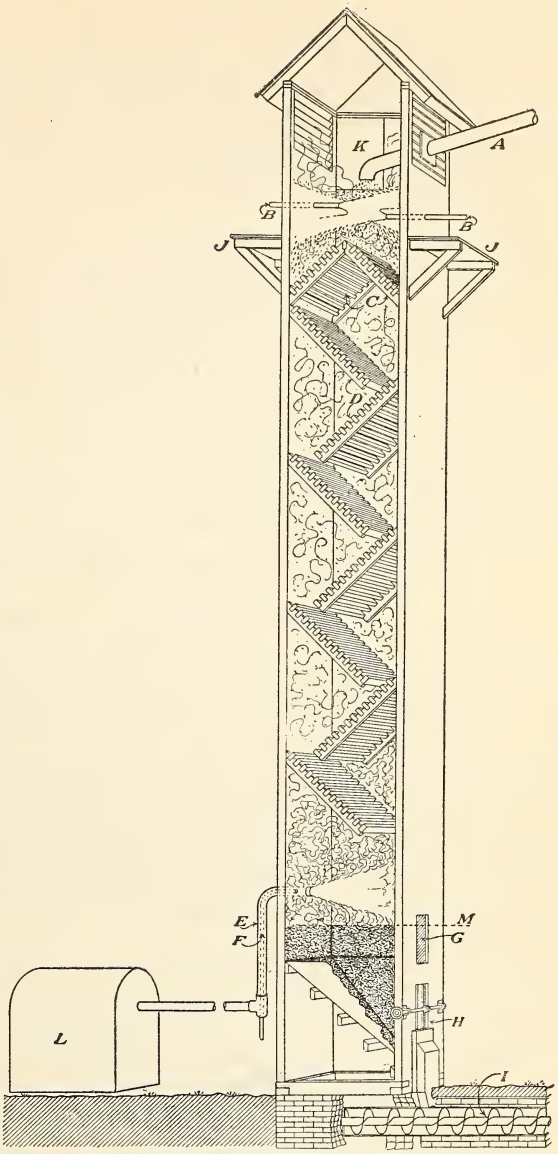

FIG. 1.—A common type of tower or chimney grain bleacher. *A*, Elevator leg which conveys grain from elevator to bleacher; *B*, steam jets which moisten grain; *C*, first break for stream of grain; *D*, deflecting shelves; *E*, pipe which conveys sulphur dioxid to bleacher; *F*, steam jet which creates suction draft in sulphur pipe; *G*, glass gauge through which height of grain in the tower is observed; *H*, regulator for grain outlet; *I*, screw conveyor which returns grain to elevator; *J*, landing on tower; *K*, door opening into tower for purpose of cleaning grain break; *L*, sulphur furnace in which the sulphur dioxid is generated; *M*, pocket in which grain accumulates, allowing better action of sulphur dioxid.

The base of the tower bleacher forms a pocket in which the grain is allowed to accumulate to a point underneath the inlet for the sulphur dioxid. Owing to the accumulation of the grain in this pocket, better action of the sulphurous acid upon the stained and discolored grain is afforded by lengthening the time it is confined in the bleacher. With this method of bleaching, the grain is in the tower about two or three minutes.

After treatment in the bleaching tower the grain is returned to the elevator bins, where it is customarily left from 24 to 48 hours, and where a large part of the actual bleaching takes place. If one bleaching fails to produce the desired result, the process is repeated.

Before loading for shipment, the grain thus treated is "run" or "handled" in the elevator for the purpose of cooling it and also to remove the sulphurous-acid odor, which is only partly accomplished. More or less moisture is lost during the handling, but the operator aims to remove no more moisture than is necessary, because the addition of moisture is one of the sources of profit in the bleaching process.

RESULTS OF SULPHUR BLEACHING.

APPEARANCE IMPROVED BY BLEACHING.

As shown in figure 2, the oats subjected to sulphur bleaching are the lower grades of white oats, the commercial grades of No. 3, No. 4, and "Sample" or "No grade" white oats usually being used. The reason that such oats receive low grades may be due to several causes, such as stain, field or mold damage, bad odors, or a low-test weight per measured bushel. When the damage is stain or mold the outward appearance of the grain is greatly changed by sulphur bleaching, and it is often difficult to distinguish between the sulphur-bleached grain and that which is naturally bright and sound, without subjecting it to a chemical test.

For the purpose of determining to what extent the outward appearance of oats is changed through sulphur bleaching, samples representing 9 lots of oats before and after bleaching were submitted to several experienced grain inspectors for grading in the regular manner, with the exception that they did not take into consideration the odor of sulphurous acid on the samples of bleached oats.

The results of this test were that 6 of the sulphur-bleached samples were classed the equivalent of a full grade higher than the samples representing the corresponding lots of oats before bleaching and 3 of the samples were raised from the average to the top of the same grade.[a]

[a] In the trading upon the grain exchanges there is at times a range of 1 to 3 cents or more per bushel in the market price of a single grade of oats, depending on the apparent quality and condition of the grain, and in order to compare values more definitely than can be done by the present specifications for grades, the terms "top" and "bottom" of the grade are used.

A comparison of the grades of oats before and after bleaching is shown in figure 2.

CHANGE IN MOISTURE CONTENT AND WEIGHT PER BUSHEL.

Samples of oats before and after bleaching were collected at various places throughout the oat-producing sections. The samples before bleaching were taken as the grain was being elevated to the bleaching tower and the samples after bleaching were obtained as the grain was being conveyed back to the storehouse or elevator bin.

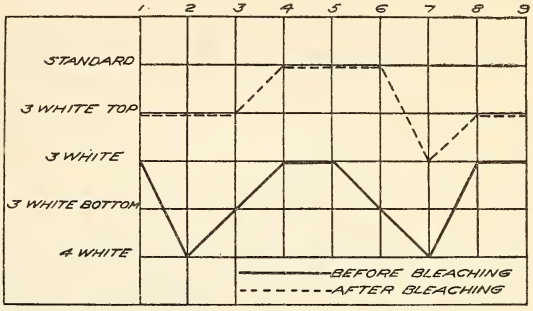

FIG. 2.—Diagram comparing the grades of oats before and after bleaching.

The moisture content of every sample was found to be higher after bleaching. The detail of samples is shown in figure 3 and the statement of percentages is given in Table I.

TABLE I.—*Moisture content and weight per measured bushel of samples of oats before and after bleaching.*

Stage of process.	Moisture content (per cent).				Weight per measured bushel (pounds).			
	Maximum.	Minimum.	Average.	Average increase.	Maximum.	Minimum.	Average.	Average decrease.
Before bleaching	14	10	11.38	.....	32	24.75	27.46	.....
After bleaching	15.6	11.6	13.17	1.79	30.5	23	26.12	1.34

The average increase in moisture, due to the bleaching, without deducting the loss due to evaporation in handling between the bleacher, the elevator, and the car (0.50 of 1 per cent), was 1.79 per cent. The relative increase in moisture was not constant, the variations being due largely to different methods of operating the various bleachers as well as to the quality and condition of the grain before bleaching.

In this connection it must be borne in mind that within certain limits an increase in moisture content results in a decrease of the weight per measured bushel. In the samples used in these investigations the average decrease in weight per bushel was 1.34 pounds as compared with an average increase in moisture content of 1.79 per cent. The difference in individual samples is graphically shown in

detail in the upper portion of figure 3, and the weights per measured bushel before and after bleaching are given in Table I. The average decrease in the weight per bushel due to the addition of moisture during the process of bleaching was 1.34 pounds; however, this decrease in weight per bushel was not sufficient to prevent the oats from being given a higher grade on account of the improvement in appearance after bleaching, as shown in figure 2.

FIG. 3.—Diagram comparing the moisture content and the weight per measured bushel of oats before and after bleaching.

ODOR BEFORE AND AFTER BLEACHING.

Commercial oats, as they reach the grain markets, vary greatly in quality, condition, and color. The odors range from a natural odor common to oats when harvested under favorable conditions down through a series of odors acquired from various weeds, the most common of which is the ragweed, and from different kinds of damage, such as "ground damage," mold, heat damage, etc.

The sulphur bleaching of oats changes these odors and generally removes or overcomes them entirely, leaving a strong sulphurous-acid

odor when the oats are freshly bleached. The odor of sulphurous acid has a tendency to disappear, especially as the oats become drier. The absence of the odors commonly found in natural oats usually arouses suspicion that they have been bleached; therefore, in order to supply the desired odor and to make the detection of sulphur-bleached oats difficult or impossible by physical examination, it is a common practice to mix unbleached oats with bleached oats. The mixed grain is seldom questioned as having been bleached; nevertheless, a trace of sulphurous acid remains and may be detected by subjecting the grain to a simple, qualitative, chemical test recommended by Carroll.[a]

GROWTH OF FUNGI RETARDED BY BLEACHING.

Mrs. Flora W. Patterson, Mycologist in Charge of Pathological Collections, Bureau of Plant Industry, made tests of samples taken from six lots of oats and barley, before and after bleaching, in order to ascertain how the bleaching process affects the fungi commonly found on the grain, of which the following is a partial report:

> The contents of all tubes were agitated in water, which was then added to sterilized culture media in petri dishes, 8 dishes being prepared from each number. These cultures now clearly demonstrate the fact that the process of bleaching inhibits the development of fungi, as the number of species is greatly reduced. Their growth is not only greatly retarded, but it is in no instance so luxuriant, even with the same species, as in the cultures made from the unbleached grain.

Unless the grain is properly cooled and dried after having been bleached it will contain an excess of heat and moisture, two factors favorable for the growth of fungi, which may result in the deterioration of the grain. On the other hand, since the fungi are partly destroyed and their growth retarded by the sulphur-bleaching process, it is probable that bleached grain will carry a higher percentage of moisture without danger of deterioration than unbleached grain of the same quality. Observations on grain in commerce seem to indicate that this is true.

GERMINATION REDUCED BY BLEACHING.

As bleached oats and barley are frequently selected for seeding purposes because of their exceptionally bright appearance, germination tests were made of both grains before and after bleaching in order to ascertain whether or not the vitality is affected by the bleaching process. The results of these tests are given in Table II.

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[a] Carroll, W. P. A Simple Method of Detecting Sulphured Barley and Oats. Circular 40, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909.

TABLE II.—*Vitality of oats and barley before and after bleaching.*

Kind of grain and laboratory No.	Final test, end of sixth day (per cent).		Kind of grain and laboratory No.	Final test, end of sixth day (per cent).		Kind of grain and laboratory No.	Final test, end of sixth day (per cent).	
	Before bleaching.	After bleaching.		Before bleaching.	After bleaching.		Before bleaching.	After bleaching.
Oats:			Oats—Con.			Barley:		
1	92.5	89.5	21	73.0	77.0	101	84.5	83.0
2	90.0	78.5	22	79.0	67.0	102	94.0	46.5
3	90.5	82.5	23	98.5	98.0	103	97.5	97.5
4	95.0	86.5	24	88.5	73.0	104	96.5	97.5
5	90.0	81.0	25	87.0	74.5	105	97.5	94.5
6	66.5	35.5	26	84.5	82.5	106	96.0	97.5
7	90.5	69.0	27	89.5	71.0	107	78.5	67.0
8	83.5	94.0	28	99.0	80.5	108	91.0	76.7
9	92.5	90.0	29	33.0	21.5	109	91.5	94.0
10	90.0	90.0	30	93.5	73.0	110	94.0	37.5
11	75.0	96.5	31	95.0	95.5	111	90.0	90.5
12	88.5	87.0	32	95.0	53.5	112	95.0	5.5
13	85.5	0.	33	89.0	40.0	113	89.5	96.5
14	92.5	9.0	34	77.5	60.0	114	94.0	97.0
15	78.0	.25	35	93.0	94.0	115	94.0	5.0
16	92.5	1.0	36	99.5	87.5	116	84.0	89.0
17	83.5	86.0	37	87.0	74.5			
18	95.5	82.5				Average for barley	97.72	73.45
19	87.0	55.5	Average for oats	86.92	68.14			
20	95.5	84.0						

According to Arthur,[a] bleached oats upon which experiments were made for the purpose of removing smut from seed grain showed 9 per cent less germination than those that had not been treated with sulphurous acid.

From Table II it will be noted that an average of 86.92 per cent of the kernels of the unbleached oats germinated, whereas an average of only 68.14 per cent of the sulphur-bleached kernels germinated, being an average of 18.78 per cent less germination in the sulphur-bleached than in the unbleached oats.

With barley the percentage of germination was also found to be lowered by the treatment. As shown in Table II, the average germination of the unbleached barley was 91.72 per cent, while the average of the sulphur-bleached barley was only 73.45 per cent, being 18.27 per cent lower than the unbleached barley. In a few instances, it will be noted, the percentage of germination of the bleached grain was decidedly lower than the check, which is accounted for by the fact that these particular lots had been twice bleached, showing that the vitality of the grain is reduced in proportion to the severity of the treatment.

FEEDING EXPERIMENT WITH BLEACHED AND UNBLEACHED OATS.

In these investigations no attempt was made to determine the effect of sulphur-bleached oats on the health of animals. However, for the purpose of ascertaining whether or not horses would eat sulphur-

[a] Arthur, J. C. Bulletin 103, Agricultural Experiment Station, Purdue University, Lafayette, Ind., 1905.

bleached oats as readily as unbleached oats, a feeding experiment was carried on at the Arlington Experiment Farm, near Washington, D. C., in cooperation with Prof. L. C. Corbett, Horticulturist in Charge, with two teams of farm horses and one team of carriage horses used by the Department of Agriculture.

The first part of the experiment extended through a period of 15 days and was confined to 2 teams of horses, which were being worked on the farm at the time, after which, for a 5-day period, the carriage team was fed. Sulphur-bleached and unbleached oats in equal quantities were fed in separate boxes at the same time to each horse of the 3 teams. In order to exclude a possible error due to the convenience in the positions of the feed boxes, which were placed side by side, the bleached and unbleached oats were fed in different boxes on alternate days. It was observed that each horse ate the bleached oats as readily as the unbleached oats. Frequently the horses ate from the boxes alternately, so that they finished eating both the bleached and the unbleached oats at practically the same time.

PROFITS RESULTING FROM BLEACHING.

There are two sources through which a profit is derived by the process of bleaching oats. (1) By purchasing low grades of oats, improving their appearance, and selling them at approximately the price of unbleached oats of similar appearance, and (2) by increasing the original weight by the addition of moisture during the bleaching process.

GAIN BY IMPROVED APPEARANCE.

From a comparison of the grades before and after bleaching, as shown in figure 2, it is obvious that sulphur-bleached oats bring a higher price than unbleached oats because of the improvement in appearance brought about by the bleaching. In order to ascertain to what extent prices are increased by bleaching, the market value of the bleached oats from the standpoint of appearance was compared with the prices current for the various grades of oats on "track" on the days when the bleaching was done.

As shown in figure 4 the range in price before and after treatment was not always constant. This was due largely to the variation in efficiency of the bleaching processes employed at the various places where the samples were collected. On the basis of the before-mentioned oat quotations, before bleaching, the minimum price per bushel was 49 cents; the maximum, 55 cents; and the average, 52.39 cents. After bleaching, the minimum price per bushel was 51½ cents; the maximum, 56 cents; and the average, 53.96 cents. An average increase in price of 1.73 cents per bushel was due to bleaching.

GAIN BY INCREASED MOISTURE CONTENT.

As shown in figure 3, the average increase in moisture by bleaching was 1.79 per cent, as determined by samples taken as the grain was being drawn from the bleaching tower. It was found, however, that in "running" and cooling the oats prior to loading into cars, approximately one-half of 1 per cent of moisture was lost by evaporation, leaving a net increase in the moisture content of 1.29 per cent, which is equivalent to 1.48 per cent increase in weight.[a]

NET GAIN RESULTING FROM BLEACHING.

The cost of bleaching grain with sulphur depends largely upon the facilities available for handling and the quantity of grain bleached. The average capacity of a bleacher is about 3,000 bushels per hour. The cost of the sulphur (20 to 30 pounds) required to bleach 1,000 bushels of grain should not exceed 50 cents. The steam required for the process is not an expensive item, as it is usually at hand for running other elevator machinery. From estimates obtained from various persons engaged in this line of work the cost of bleaching, when the plants are running full capacity, varies from about one-eighth to one-quarter of 1 cent per bushel.

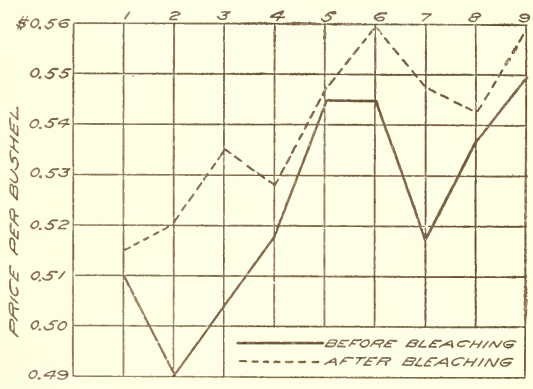

FIG. 4.—Diagram comparing the price per bushel of oats before and after bleaching.

Computed on a basis of 54 cents per bushel for the oats (the average price at the time of bleaching), the gain in weight of 1.48 per cent shows an average gain in the price received of 0.78 of 1 cent per bushel from the addition of moisture alone, which, added to the average gain of 1.73 cents per bushel from advanced grades by reason of the improved appearance of the oats, shows an average gross gain of 2.51 cents per bushel. Deducting from this the greatest estimated cost of bleaching (one-quarter of 1 cent per bushel), the net profit due to the process of bleaching would be 2.26 cents per bushel, which, on the average carload of 1,600 bushels, would amount to $36.

[a] Circular 32, Bureau of Plant Industry, U. S. Dept. of Agriculture, entitled "Moisture Content and Shrinkage of Grain," explains the reason for this difference and how it is calculated.

SUMMARY.

(1) Oats and barley of inferior quality and condition may be made to resemble that of a better quality by bleaching.

(2) A profit is derived not only from changing the appearance of the grain but also by increasing the original weight by the addition of moisture.

(3) Because of the fungi being partially destroyed by the bleaching it is probable that bleached oats will carry a higher moisture content than unbleached oats with less danger of deterioration.

(4) The vitality of oats and barley is impaired by bleaching and a heavy bleaching is especially harmful.

(5) Preliminary feeding experiments with both bleached and natural oats showed that horses ate one as readily as the other.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *December 16, 1910.*

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